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CONCEPTS OF SCIENCE
in Europe and Asia

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Preface

This lecture was delivered on the occasion of the official opening of the International Institute for Asian Studies at Leiden on October 13, 1993. I am grateful to the Board of the Institute for inviting me and bestowing this honor upon me. The lecture makes use of findings that are part of a larger undertaking to which many friends and colleagues have already contributed and which is still in progress. In its present form, it formulates some first tentative conclusions and incorporates information and insights for which I am particulary indebted to Derek Herforth, David Johnson, David Keightley, Hugh McLean and Jeffrey Riegel at Berkely, Han den Heijer at Leiden, Paul Kiparsky at Stanford and Henk Verkuyl at Amsterdam-Utrecht. None of these scientists are responsible for the views expressed here.

Frits Staal

1. Europe: *Newton's Lesson*

It has long been maintained, especially by Westerners, that the West must civilize the rest of man- and womankind. It is taken for granted that Western civilization includes not only ethics, morality and human rights, but also science and technology along with the implied notions of rationality and progress. I shall not talk about the former cluster of concepts but in regard to the latter, a curious situation has arisen within the West itself. Some praise science as if it were a religion that must be accepted without question or criticism. Others treat is as an evil that has to be exorcized. The pro-science camp invokes the Enlightenment, rationality or progress. The anti-science camp invokes ideals of the Romantic Period or philosophers who have shown that there are problems about rationality and that science does not always progress, is not always objective and is often linked with power structures. It is now widely recognized that some sciences have turned into authoritarian disciplines, are linked with powerful lobbies or tainted by association with weapons of mass murder. Others, it should be added, are weakened to the point of extinction. I have heard it maintained that everything can be explained by the simple fact that science was produced by the left hemispheres of Dead White Males. Whatever the spectrum of opinion, all these claims have one assumption in common: good or bad, science is held to be Western, its roots firmly planted in the soil of ancient Greece. Opinions are divided on the issue whether Christianity has contributed to that heritage or posed obstacles to its free unfolding, but the majority of historians of science lean toward the latter view.

The assumption of the Greek origin of science is still widely held, but it, too, has been challenged, primarily because it is well known that the Chinese, for example, invented gunpowder and the compass while the Indians contributed zero. But were those discoveries part of a well designed development, or did the Asians happen to stumble upon them? After all, if we take the example of acupuncture, it is agreed that it can relieve pain, but if we look at Chinese theories offered to explain it, we have to record that modern

scientists regard those explanations as worthless. Perhaps acupuncture was just one of those chance discoveries. Or is medicine always that way? Or are there different kinds of science in East and West?

I shall first take a closer look at the assumption that science is Western and for this we shall have to begin with the word itself. For "science", even in English, does not denote a single and stable concept. There exist confusing differences in usage between English (American as well as British) and other European languages. English *science* refers primarily to the physical and life sciences, although it includes mathematics which is not about physical or living things. French *science*, spelled the same but pronounced differently, like German *Wissenschaft*, Dutch *wetenschap* or Russian *nauka*, applies to human, social, natural and other domains. In English, there is confusion about human sciences, humanities, letters and even arts. In Dutch and German, the terms *geesteswetenschappen* or *Geisteswissenschaften* are used although no one agrees or even knows what *geest* or *Geist* refers to. The French incorporate these same disciplines among the *sciences humaines*, which in German or Dutch suggest anthropology, in French a *science sociale.*

These confusions reflect not only the rapid expansion of knowledge, but tradition, fashion and other backgrounds. During the middle ages, the classification of the "seven liberal arts", Greek in origin, included the *Trivium* of grammar, rhetoric and logic and the *Quadrivium* of arithmetic, geometry, astronomy and music. The first three overlap with philosophy and the last is still regarded as an art. From the twelfth century, these sciences were updated with translations from Arabic, Hebrew and Syriac, including Greek as well as Oriental knowledge, physics, and other disciplines, called *natural philosophy* for another half millennium. After Newton and Leibniz, still *natural philosophers,* the mutually incoherent concepts of modern science developed.

Though a white male, I am not dead and therefore able to see that Europeans will not find outside Europe parallels to developments about which they themselves are so confused. To compare fruitfully we have to be flexible, and not lay down precise distinctions ahead of time especially when such

distinctions are constantly afloat. Perhaps we shall come up with firm distinctions in the end, long after my talk. For the time being I shall give the term "science" a wide extension, use labels only if I have to and include all the disciplines I have mentioned, in other words, all forms of systematic knowledge of ourselves and of the universe in which we live.

The ancient Greeks developed logic and a notion of rationality as deduction best exhibited by Euclid's geometry. These discoveries contributed substantially to the development of Western science. Other things had to be added, for example, observation and experimentation. Aristotle did not only theorize but made observations in a wide range of sciences, including physics, psychology, politics and poetics. But when Aristotle was turned into an authority, progress was blocked. For it is characteristic of science that it looks forward and not back. It is helpful to stand on the shoulders of giants (Newton used the expression) but only if it enables us to see things the giants themselves had missed.

The idea of progress is not essential to science which is first and foremost interested in truth. But experience teaches that truth is only reached after much untruth has been cleared away. Just as the evolution of a life is in some respects an adaption to the environment, the history of science is in some respects an approximation to truth. It is obvious that progress is not universal; happiness, for example, has not increased in an obvious manner or increased at all. But whatever the claims of relativistic theories of science, which always invoke Thomas Kuhn's paradigm shifts, it is undeniable that we – that is to say: the specialists among us – know and understand a great deal more than our most well-informed ancestors. All sciences did not develop in neat, progressive lines, there have been *culs-de-sac* and much knowledge is undoubtedly lost, but there have been large breakthroughs especially in the physical and life sciences, which have not only increased our knowledge of facts but fundamentally deepened our insight in, for example, the universe, life or the human brain. This is true of European science after the Scientific Revolution and is not invalidated by the expansion of new problems and unanswered questions that is also part of scientific progress.

The idea of progress was not common in ancient Greece. According to E.R. Dodds, it was confined to the fifth century B.C. and the most explicit statements of the idea refer to scientific progress and come from working scientists or from writers on scientific subjects. Dodds concludes with a generalization:

> There is a broad correlation between the expectation of progress and the actual experience of progress. Where culture is advancing on a wide front, as in the fifth century, faith in progress is widely diffused; where progress is mainly evident in specialized sciences, as in the Hellenistic Age, faith in it is largely confined to scientific specialists; where progress comes to a virtual halt, as in the last centuries of the Roman Empire, the expectation of further progress vanishes. [Dodds 1973: 24–25]

If we measure the present by this classical yardstick, it would seem that progress takes place nowadays only within specialized sciences. But in "specialized" lies the rub. More than in any other civilization, fundamental progress in understanding is now coined in artificial languages – especially mathematical formulas – that are so specialized and difficult to understand, that the public and many thinkers and trend-setters can afford to ignore them. This helps to explain the co-existence of the two opposing camps mentioned at the outset of my lecture.

Just as claimed progress may not be real, factual progress may be combined with its explicit denial. The Pythagoreans attributed many later results to Pythagoras. This was partly due to mathematical manuals edited by *The Pythagoreans*, an anonymous group like *Bourbaki* in contemporary mathematics [Van der Waerden 1979: 338]. Plotinus, whom we call a Neo-Platonist, was similarly convinced that he simply expounded Plato and that his doctrines were no novelties or inventions although much in his philosophy was new. His method, moreover, was philosophic, not commentatorial: he did not accept truths because he had found them in Plato; he found them in Plato because he had accepted them [Dodds 1973: 128].

This curious interpretation of discovery as re-covery was destined to have a great future. Plato had laid its philosophic foundation by stating that knowledge is memory. This view was modified in an unexpected manner by Christianity which accepted a divine revelation that, by definition, could not be improved upon. It is not impossible that the myth of Pythagoras as the great sage and progenitor of science was a late Greek response to the increasing popularity of Christ. According to St. Augustine, Moses and the early prophets possessed knowledge that Egyptians or Greeks could not fathom. Others went further and believed that the Greeks had learnt everything from the Hebrews to whom all true wisdom had been given. According to Roger Bacon in the thirteenth century – not Francis of three centuries later who has been heralded as the originator of scientific method – the divine wisdom of Christianity had been abused by Zoroaster, Prometheus, Hermes Trismegistus and other unbelievers [Crombie 1975: 221]. During the Italian Renaissance, the fortunes of some of these shadowy precursors changed again: Marsilio Ficino, Pico della Mirandola and Giordano Bruno were all trying to find out the truth about Hermes Trismegistus and whatever else they thought was part of hermetic or gnostic tradition.

But how can we know that there has been progress unless we know the past? And how do we know the past? The answer is, as always in science, that knowledge springs from intuitions steeped in facts, sharpened by logic and continuously tested by both. When studying the past it is unavoidable that we use modern yardsticks. We talk about solid wheels from the point of view of wheels with spokes and other means of transportation with which we are familiar. This holds for technology and science and Gilbert Ryle has formulated it for philosophy:

> There is, of course, always a considerable hazard in attempting to elucidate a doctrine of an earlier philosopher in the light of subsequent and especially of contemporary doctrines. (...) But the opposite policy of trying to chart the drift of some adolescent theory without reference to the progress of any more adult theories is subject not to the risk but to the certainty of failure. We cannot even state what was a philosopher's puzzle, much less what was the

direction or efficacy of his attempt to solve it, unless subsequent reflections have thrown a clearer light upon the matter. [Ryle 1939: 324–5]

Let us see what happens when a historian of science wavers – an example from Islam but not from the natural sciences to which the Arabs contributed so much. In the eleventh century, al-Bīrūnī, who was also an astronomer, made a study of society in Islamic countries and India, thus paving the way for the work of Ibn Khaldūn who has often been called the first sociologist and historian of societies. In the words of the contemporary historian of Islamic science Seyyed Hossein Nasr:

> The scholar who studied man most objectively, and in a way provided the kind of materials upon which Ibn Khaldūn could base his general observations on human history, was al-Bīrūnī who made a study of both Islamic and Indian society; it was about the latter that he wrote his memorable *India*, a work that is without question one of the most scientific and objective studies of man and his society made in medieval times, at a time when, in the Western world, such studies did not pass beyond the level of chronicles. [1968: 231]

In stressing the scientific and objective study of humans, Nasr follows E. Sachau, the German 1879 translator of the text [see also von Grunebaum 1946: 245–6], and speaks with the voice of a historian of science who accepts contemporary knowledge as his yardstick. But this is inconsistent with the fundamentalist denial of progress that he espouses when writing *about* the history of science:

> Our aim is not to examine the Islamic sciences from the point of view of modern science and this 'evolutionist' conception of history; it is on the contrary to present certain aspects of the Islamic sciences as seen from the Islamic point of view. [1968: 21]

The great historian of Chinese science, Joseph Needham, has objected to this perspective because "it divorces Islamic natural science from the grand

onward-going movement of the natural science of all humanity. (...) That would be going back, and there is no going back" [Needham 1976: xxvi–xxvii]. Needham adds:

> To write the history of science we have to take modern science as our yardstick – that is the only thing we can do – but modern science will change, and the end is not yet. [1976: xxxi]

Needham himself has been criticized, for example by Nathan Sivin according to whom the history of science involves not the counting up of isolated discoveries, but "the confrontation of integral complexes of ideas with their interrelations and articulations intact", and "those whole systems of thought which have served as the matrices of discovery" [Needham 1976: xxix]. Sivin does not, like Nasr, accept an absolute truth, but his relativistic position imposes similar strictures. Here is a danger of getting drowned in very deep waters, but I am happy to report that there is a simple way out.

Newton, the paragon of modern science, was a learned historian familiar with an extraordinary wide range of ancient knowledge and wisdom. He deeply studied the Old Testament although he did not think that it held more inherent truth than the records of the Egyptians, Phoenicians or Chaldaeans [Westfall 1986: 232]. He believed in esoteric traditions handed down in an unbroken chain back to the original cryptic revelation in Babylonia. It may come as a surprise to modern scientists, but not to us who have just examined the earlier history, that Newton felt even in his most creative work in physics, that he was recovering ancient wisdom that Pythagoras, Democritus, Solomon, Moses and others had already possessed but hidden in parabel and symbol.

Newton's beliefs are expressed in his manuscripts, at least a million words on alchemy and ancient traditions contained in a large box that he took with him from Cambridge to London and left behind. These papers are beginning to be published only now because neither positivist historians of science nor religious authorities wanted to see them. The economist John

Maynard Keynes, a lifelong student of Newton, writes: "Bishop Horsley was asked to inspect the box with a view to publication; he saw the contents with horror and slammed the lid" [Keynes 1951: 317]. According to Keynes, Newton was the last of the Magi rather than the first modern physicist. Here is what a contemporary historian writes about Newton's interest in alchemy:

> Although one can trace a rising curve of sheer quantity in the period before the *Principia*, half or most of the papers, that is, more than 600,000 words devoted to alchemy, date from the early (16)90's, immediately following the *Principia*. This fact strikes me as the most significant conclusion to emerge from a study of the papers in chronological order. Newton's interest in the art was neither a youthful frolic nor an aberration of senility. It fell squarely in the middle of his scientific career, spanning the time of most of the achievements on which his reputation rests. Indeed, alchemy appears to have been his most enduring passion. [Westfall 1975: 195, adding: "It is reasonable to surmise that alchemy has never had a more informed and perceptive student"]

Although Newton did not publish any of his alchemical and historical writings, he paid attention to every comma in the text of the *Principia* that appeared in 1687 at the urgings and with the support of Edmund Halley. The *Principia* presents its results in the form of deductions, in simple Latin ready to be mathematicized as was done by Euler within a century. Newton's reputation would be different if he had derived the laws of motion from Hermes Trismegistus.

Apart from science, Newton teaches us an important lesson: Look at the results, not at what scientists say or believe about it. If we had to confront integral complexes of ideas with their inter-relations and articulations intact, and pay attention to whole systems of thought which have served as the matrices of discovery, we would have to evaluate Newton's physics in the light of his manuscripts and much else. But the interest of science lies in results that have been *abstracted* from their context and the historian of science must similarly *abstract* from context and background. Having done that, he may or may not comment on the place of science within a given civilization.

History itself has taken Newton's Lesson to heart. Newton is known for the results established in his physics and schoolchildren are taught his laws of motion. Only historians are familiar with the context of their discoverer's beliefs. Science is not validated by tradition or cultural background, but by facts and logic.

Newton's Lesson explains the rapid expansion of science all over the world among peoples that had and did not have science before, but its significance lies deeper. Pythagoras was a vegetarian who believed in transmigration, Kepler an astrologer, Newton an alchemist, L.E.J. Brouwer a theosophist, and Srinivasa Ramanujan, the greatest Indian mathematician of the last thousand but not of the last two thousand years, attributed his theorems to the South Indian goddess Namagiri. About most scientists we know nothing but Newton's Lesson suggests that it doesn't matter because science is universal.

2. China: *Fabulous No Longer*

The concept of objectivity upon which Hossein Nasr stumbled need not occupy much of our time. I have seen objectivity attacked frequently, but no attack I am familiar with has been able to do without that very notion. The concept of objective truth is basic to the search for knowledge and the backbone of science. If it is absent from Asia there cannot be Asian sciences and we cannot make the transition from West to East that some of you may have been waiting for.

Fortunately, we don't have to construct a complex argument to demonstrate that looming somewhere in Asia there is that profound insight. India's most well-known philosopher, Śaṅkara (eighth century A.D.) formulated it lucidly and with a degree of succinctness that compares well with the best philosophers have come up with:

> Knowledge of the nature of a thing does not depend on human notions or on authoritative statements. It depends only on the thing itself. [*Brahmasūtrabhāṣya* 1.1.3]

We have already seen that knowledge does not depend on the boundaries of sciences which reflect changing human notions. The excessive preoccupation with frontiers and the concern about purity are sure signs of the immaturity of a discipline. Historians of Asian science confirm the floating of boundaries there though they formulate it as if it were something special:

> Many of the familiar developments of modern science are not to be found in the Chinese schema. We find it convenient and useful to think in terms of 'Chinese biology' and 'Chinese astronomy', and are often tempted while doing so to forget that no such discipline as the former ever existed, and that the structure of the latter and its role in intellectual history has little in common with corresponding factors in the West. [Sivin 1968: 6–7]

> There was never in India a *jāti* ('class') of mathematicians and rarely anything that could be called a school; most mathematicians were *jyotiṣīs* (astronomers or astrologers). Therefore, the mathematical literature consists either in the form of chapters of astronomical *siddhāntas* or of treatises composed, with a few exceptions, by scholars who were also authors of astronomical texts. [Pingree 1981: 56]

What is stated here of Asia is also true of Europe. Many European "natural philosophers" were astronomers, mathematicians, philosophers, alchemists, astrologers and dabblers in other subjects. I conclude that there seem to be things like sciences in Asia, but their outlines are not sharp and so it is not clear whether they correspond to the sciences of Europe whose frontiers are also fuzzy. So let us take a look at some of the things themselves that have been called Asian sciences. But now we come upon another obstacle: the subject is enormous and is only beginning to be studied seriously. There are few experts and I am not one of them. I shall therefore confine myself to a few features that bear on conceptual issues.

I shall further confine myself to the scientific traditions of the two largest and oldest still living Asian civilizations: China and India. This is not because there are no other sciences in Asia, but it is on these two that the others largely depend. The exceptions include medicine and mathematics, which developed locally, for example, in Japan and Southeast Asia where astronomy, on the other hand, was Chinese or Indian.

If we confine our attention to China and India, what place do we assign to the Near East? Let us start with some facts. The Old-Babylonians developed an algebraic or computational mathematics before 1700 B.C. [Neugebauer 1957: Chapter II; Seidenberg 1978 and other articles] and their earliest grammatical texts date from around the same period [Jacobsen 1974: 41]. The needs for mathematics vary, but linguistics seems to have arisen then and there because of serious concern about the observation of a classical literature written in a language (Sumerian) that was becoming obsolete. Old-Babylonian mathematics did not improve much during the next one thousand years, but it

contributed to the birth of mathematical astronomy during the Seleucid Era, after 300 B.C. Combining Greek insights with this ancient Near Eastern heritage, Hellenistic science was the foundation for European and Islamic science and influenced (especially in the area of astronomy) India and China. As for Egypt, you might wonder whether we shouldn't also regard it as part of the Near East. If Neugebauer is right, it does not matter; for he arrived at the conclusion that "ancient science was the product of very few men; and these few happened not to be Egyptians" [1957: 91]. The later history of Near Eastern science is concerned with the Islamic sciences which inherited the Hellenistic and are part of the same multiform and multi-branched tradition. For Europe, Arab science was a bridge not only to ancient Greece but also to the rest of Asia. It included Greek and Indian mathematics, a combination necessary but not sufficient for the genesis of modern science [A.C. Graham 1973: 68]. Muslim curiosity about the world survives in the Arab saying: *talab al-'ilm ḥattā fī 'ṣ-ṣīn*, "Seek knowledge even if you have to go as far as China!"

We may generalize that there seem to be, in Eurasia, three scientific traditions to a large extent independent from each other: the Western which started in the Ancient Near East, includes the European and Islamic scientific traditions and should therefore be called "West Eurasian"; the Chinese and the Indian. I use the term "West", oriented as it is, to refer to Europe (that is, North West Eurasia) and, if need be, North America; and "India" and "China" as appellations for the classical civilizations whose scientific literatures were composed in Sanskrit and classical Chinese from roughly 1,000 B.C. The modern nations India and China belong to regions now referred to as South and East Asia that include also Pakistan,Nepal, Shri Lanka, Tibet, Korea, Japan, and other countries. It would be possible to upgrade the appellations and refer to the three large traditions as South, East and West Eurasia, but I retain "India" and "China" because they were less ancient and more homogenous in language than West Eurasia.

I shall begin with China where I have to be brief although its history is long because I do not know Chinese and have to depend on the literature in Western languages and my colleagues. Fortunately, there exist for China a work in English, still in progress, that summarizes almost all previously published

information and incorporates a staggering quantity of newly discovered material: I am referring, of course, to Joseph Needham's *Science and Civilisation in China.* The first volume was published in 1954 and by now there are about fifteen volumes and parts of volumes, separately bound. Much of the work of Needham and his collaborators is concerned with what is now called technology for it is in this area that the Chinese especially excelled. Among its topics I mention astronomical instruments, cartography, mechanical, civil and nautical engineering, paper and printing, textiles, metallurgy and ceramics. But there is also a great deal that would now be regarded as pure science: mathematics, astronomy, geology, physics, botany, and zoology. Intermediate topics range from medicine to alchemy, including disciplines for which English lacks the appropriate terms unless we create neologisms such as "acupuncture". In the short time at my disposal I cannot give you much of an idea of this enormous wealth of material. I recommend that you take a look or another look at some of these volumes. What I can do is quote what eminent historians of science have had to say about them – for example, D.J.de Solla Price [1971: 17–18]:

> In my estimation, the essential contribution made thus far by six volumes of *Science and Civilisation in China* lies in the systematization and presentation in English translation or summary of the substantive content of the otherwise ill-digested bulk of Chinese scientific and technical literature. Here we have the raw material on which generations of later scholarship can be founded. Here at last we have some map to tell us where to look, and some indication at least of what we shall find. (...) Even a casual browsing through any single tome is enough to break the stereotype that most Westerners will have formed about Chinese science and technology. It is not a matter of peasant-farmer and mandarin-scholar. What emerges is certainly a culture with technicalities just as complex as our own, science just as deep, philosophy and experience in manipulating and transforming nature just as indissolubly bound together. Often, much the same sequence is followed in the discoveries from both traditions; sometimes one leads, sometimes the other. There can be no doubt that Chinese science and technology have been just as inventive, just as good, just as bad, as the science and technology of the ancient and medieval West.

Needham's thesis is that European and Asian sciences occupied similar levels until the Scientific Revolution, when Europe jumped forward with unprecedented rapidity. Recent scholarship has been critical of the idea of the Scientific Revolution shaped by historians of science such as Alexander Koyré and Herbert Butterfield, but no one has given us a more adequate picture of that explosion of scientific activity that began in the seventeenth century, continues unabated to the present day and has produced a civilization that, more than any other, is characterized by science. Though there are many hypotheses about it, the occurrence of the Scientific Revolution has not been satisfactorily explained and cannot be explained without adopting a comparative perspective, that is, unless scientific developments outside Europe are taken into account.

Sinology appears to be critical of Needham; many works about Chinese civilization simply ignore or relegate him to footnotes. It is said that his dates and translations are not always reliable which is consistent with De Solla Price's statement, that we have here the raw material on which generations of later scholarship can be founded. But the grand statement stands unrefuted and we should not forget a simple fact. Orientalists, who have spent years of their life learning difficult classical languages, are rarely curious about science. Life is short. An Asian perceives perhaps more easily what Shigeru Nakayama (1973: 35) points out about Orientalists in general: they are not interested in the Asian sciences because they are "usually motivated by love of the exotic and extra-ordinary". Raymond Schwab and Edward Said have put this observation in cultural and political contexts.

Many Chinese and some Western Sinologists are exceptions to the Sinological neglect of Needham. Sivin, already quoted, writes:

> Ponderous disquisitions on why China had to get along without anything that could be called scientific thought, and with only primitive technology, are much less common now that Needham has shown with massive documentation in volume after volume that their premises are based on garden-variety ignorance. [Sivin 1973: xi]

Derk Bodde counts Needham's work as one of two outstanding scholarly achievements that have greatly enlarged our understanding of Chinese civilization during the second half of the twentieth century. The other is archeology, "still being continued in China by dozens of scholars and hundreds of anonymous workers" [Bodde 1991: 1]. A.C. Graham writes:

> I do not hesitate to apply the adjective 'great' to Needham's work, although like other sinologists I am aware that his linguistic understanding is below the highest available standards. The best qualifications in both sinology and science are unlikely to meet in one person whose native language is not Chinese, and it is lucky that there is someone who has come so near to combining them. [Graham 1973: 46 *note 2*]

Let us look at a few examples. Needham provides scores of cases of naturalists' scepticism with regard to common superstitions. One of his favorite scientists of the sixteenth century, Li Shih-Chen, called "Prince of Pharmacists", was an experimenter critical of medieval explanations that saw miraculous metamorphoses throughout nature. In Volume 6, Part 1 [1986: 318–9], we read that the soya-bean had been considered an antidote to indigestion and intestinal poisoning, but Li demonstrated that it only has effect when it is accompanied by a drug Needham identifies as *Glycyrrhiza glabra.* The phallus-shaped Balanophoraceous plant (*Cynomorium coccineum*), a tree-root parasite, was believed to arise from the seminal emissions of wild horses, but Li showed that it originated from seeds like any other plant. Needham says [318 *note h*]:

> In most of these cases, Li ends with a formula of gentle irony: 'Therefore they cannot *all* be generated in the way that has been claimed'.

Another volume [Needham 1976: 97] quotes Li on another bit of fanciful folklore about amber turning, over the millennia, into a fungus and then into vitriol:

> All this is in general fabulous talk and cannot be taken seriously.

Needham is contemptuous, on the whole, of the anti-scientific influence of Buddhism. The extensive literature translated from Sanskrit into Chinese included not only Buddhist doctrine but ritual, literature and "a veritable labyrinth" [Needham 1956: 423] of schools of philosophy. But it contained also science (especially medicine and astronomy) and the philosophy was not only Buddhist but Indian and included subjects of scientific interest such as perception [Matilal 1986] and inference [Staal 1988]. While the Indians knew nothing of Chinese science or philosophy, the Chinese were reasonably well informed about the Indian which did not fail to exert its influence, for example, on Neo-Confucianism.

Needham is less scornful of Confucian ethics but traces the origins of most of the sciences to Taoism. Taoist alchemy and ideas about the "interior landscape" [Schipper 1982] paved the way for chemistry and physiology. Needham compares Taoist and Indian Tantric cults, esoteric like the hermetic and linked with medicine, psychology and therapeutic rituals. In these areas where Indian and China touched across the Himalayas, where rites, mantras and meditation, spirit-possession, sexual gymnastics, breath-exercises and martial arts came together, no one has yet been able to sort out what came from where and what is science – possibly true – or superstition – definitely false.

It is instructive to compare the Buddhist expansion with its Christian counterpart but of greater significance for the history of science was the extensive translating activity from Sanskrit into Chinese, the Asian precursor to the translations from Greek and Arabic that took place a millennium later in Europe. These studies are the precursors of "Orientalism" and might have been called "Occidentalism" – but in Chinese – if Buddhism had established itself as firmly in China as Christianity did in Europe. Another precursor is al-Bīrūnī, a Muslim orientalist, *pace* Edward Said, who translated the *Yogasūtra* from Sanskrit into Arabic. Mathematics and astronomy depend least on the intermediary of natural language, but all sciences require for their transmission accurate translations and interpretations. Orientalism does not merely provide the materials for the present essay, it played a major role in the development of science and modern science would not exist without it.

3. India: *Preferably Formal*

I HAVE BEEN VERY VAGUE AND UNSPECIFIC about China and now come to India which is sometimes regarded as my special field. But the idea that a person with some training in a classical Asian language is an authority on anything written in that language is one of the wrong-headed and debilitating features of Western academia – a feature, I hope, that the new Asia Institute will help to overcome. Unlike his Orientalist colleagues, a Professor of German in a Western university is not expected to be an expert on Kepler, Kant or Einstein though all of them wrote in German. How could a Sanskritist be more than a specialist in one or two of the many domains of human activity and civilisation about which there exist a Sanskrit literature more extensive than any mortal can muster? I know of the bulk of Indian science just as little as of that of Europe or China and can do no more than scratch the surface and formulate impressions.

Europeans discovered China during the Enlightenment and India during the Romantic period. We are therefore predisposed to find in China science and in India religion. The absence of an Indian Needham supports these constructs. But there are numerous monographs on Indian sciences including ongoing series on Indian mathematics and astronomy published from New Delhi and Lucknow, and a many-volumed *Census of the Exact Sciences in Sanskrit* by David Pingree. My impression is that the Indian scientific tradition is as rich as the Chinese, an impression confirmed by Needham's work, which does not only deal with China but abounds in references to Western (including Islamic) and Indian sciences. India is richer than China in abstract and theoretical sciences such as mathematics and logic. Needham has, of course, discussed this issue and characterized Chinese science as organic and therefore more up-to-date than much of modern Western science which is, as Dijksterhuis described it, mechanistic. Needham writes: "Chinese mathematical and theoretical backwardness was clothed in an organic philosophy of nature closely resembling that which modern science has been forced to adopt after three centuries of mechanical materialism" [quoted by Nakayama 1973: 39].

An example of abstraction and reductionism that occurs, albeit at the speculative level, in both India and classical Europe but not in China, is the theory of atoms. The term reductionism may have bad connotations, but most sciences cannot exist without it, that is, without going beyond the phenomena and postulating an underlying reality to which the phenomena are reduced like heat is to motion; or, to put it in simpler terms: without postulating a hierarchy of sciences. To complain about reductionism or "bare bones is like criticizing the physicist for failing to capture the richness of the rain forest" [Quine 1981: 186].

I shall not further comment on the natural sciences whatever promise their study may hold. Let us rather take a brief look at the human sciences which India emphasized more than Europe or China. It is a truism that, in the West, the study of the human animal has long been and continues to be neglected. A mere glance at the harvest of discoveries in the natural sciences demonstrates that humans have been left behind. Adding the social to the human sciences would not redress the balance; scientific attention is unevenly distributed on a scale that would astonish a visitor from another planet eager to learn about the people who inhabit ours. In China and Europe there has always been interest in man though not in woman; but it was chiefly philosophic or moral and rarely led to scientific analysis. One need only glance at the statements of two great humanists from both civilizations to see how anti-scientific they are: Socrates [469–399 B.C.] is depicted as saying, at the outset of the *Phaedrus*: "the men who dwell in the city are my teachers, and not the trees or the country" (transl. B. Jowett); Hsūn Tzu [c.313–c.238 B.C.] declared at the outset of his "Discussion on Heaven" that "Only the sage does not seek to understand heaven" (transl. B. Watson). India saw, like Aristotle, that human being can be analyzed rationally like any other object of knowledge.

Ancient Indian civilization was an oral tradition and the oral transmission of the tradition became the first object of scientific inquiry. Thus arose two human sciences, closely related to each other in their formal structure: the sciences of ritual and language. The close relationship between these two is not apparent to us because, in Europe, a science of ritual does not exist and linguistics developed late, after being influenced by India. In India, the absence

of writing and the belief that Vedic ritual and the Sanskrit language are eternal and display constant and unchanging regularities, inspired the discovery of *rules* or *sūtras* which are the abstract expressions of those regularities. When expressed through a semi-artificial type of Sanskrit, these rules are the closest Asian parallels to the mathematical formulas of the modern West that express the regularities of nature. That erroneous beliefs are at the background of these achievements supports and is supported by Newton's Lesson.

Among the many discoveries of the ritualists I mention two: the notion of metarule which is a feature of modern Western logic as indispensable to formalized mathematics as it is to computer science; and the notion of rule order, a feature of modern linguistics although possibly on the verge of being replaced by more general principles and conditions. "Meta-rules" are simply rules about rules. "Rule order" is easiest understood in the ritual context: the rules about lighting the fire have to operate before those that describe how oblations are made into it. In linguistics these rules occur at a more abstract level. Paul Kiparsky has provided me with the following example from English phonology (note that phonology is about *sounds*, not *spelling*):

Rule I describes that the sound *t* is replaced by *s* when followed by *y* except after *s*. Thus, president → presidency, idiot → idiocy, but pederast → pederasty.

Rule II describes that *s*, *t* and *z* are replaced by the corresponding palatals *š*, *č* and *ž* when followed by *y* followed by a vowel. Thus, coerce → coercion (*š*), suggest → suggestion (*č*) and confuse → confusion (*ž*)

By themselves, Rule I would predict: presiden*s*ial and Rule II: presiden*c*ial (*č*), both incorrect. If rule I is applied to the output of II, nothing happens. But if II is applied to the output of I, the correct form presiden*t*ial (*š*) is derived and explained.

The Sanskrit grammarians used rules of precisely this form and demonstrated in a similar manner why many of them have to be ordered. In

consequence of metarules, rule-order and other formal properties of rules, Pāṇini developed Sanskrit grammar as a derivational system in some respects more sophisticated than the deductive system of Euclid (Staal 1963, 1965).

If I were forced, at this point, to offer generalizations, I would stick out my neck, disregard scholarly qualification and suggest the following theses as topics for discussion. Science is universal and its main branches developed in all the great civilizations. This is not surprising because we are all humans with common characteristics, inhabiting the same universe and in equal need of reliable knowledge. The great traditions of Eurasia are basically similar but there are differences between them in character and emphasis. West Eurasian science is characterized by an emphasis on nature and punctuated increases and decreases in theoretical and empirical sophistication; Chinese science by concreteness, experimentation and an organic outlook; Indian science by formal analysis and an emphasis on human theory. All Eurasian sciences reached similar levels until the sixteenth century after which the European members of the family spiralled ahead. All sciences accepted, after initial equivocation, that the universe is one.

I don't know how much I made to-day but I shall conclude with some notes on progress. That the Asian sciences presuppose progress even if that presupposition is not often made explicit is obvious from the successive approximations of the value of π. The Chinese, who started postulating that the circumference of a circle is three times as long as its radius, soon proceeded to 92/29 or 3.1724 (around 130 A.D.). Working in the third century A.D. with polygons inscribed within a circle, Liu Hui arrived first at 3.142704, which is slightly better than Archimedes 500 years earlier, and then proceeded to 3.14159, which is better than Ptolemy around 150 A.D. After these preliminaries, the Chinese picked up speed. By the fifth century, when Western science had begun to stagnate, they reached 3.1415929203 which is better than Adriaan Anthonisz of Alkmaar in the sixteenth century [Needham 1959: 100–101]. For the Indians we can trace a similar development leading to Āryabhaṭa's fifth century approximation of 62832/20000 or 3.1416. Better approximations were given by the Kerala mathematicians of the fourteenth and fifteenth century, who also

discovered the infinite-series expansions of sine, cosine and tangent, rediscovered independently by Newton and Leibniz in the seventeenth century.

The progressions of these numbers are telling and if I had time I could try to show that many of the great natural philosophers of India, from Āryabhaṭa in the fifth to Mādhava in the fourteenth century, stood on their predecessors' shoulders and made progress in a number of astronomical and mathematical disciplines and especially in algebra. For the later periods, some lines of transmission from teacher to pupil have been published by Sarma [1972] and Pingree [1981: 123–130]. But I shall only refer to an exception: a case of regress. Āryabhaṭa's defended the diurnal rotation of the earth which implies a heliocentric view that can probably be traced back, via Persian and Seleucid intermediaries,to the Greek astronomer Aristarchos of the third century B.C. [van der Waerden 1970]. None of the three great theorists of the heliocentric universe, Aristarchos, Āryabhaṭa or Copernicus, could convince their contemporaries of the correctness of their revolutionary hypothesis, but Copernicus was lucky in being succeeded by Galilei and Kepler who were successful. Āryabhaṭa's commentators were embarrassed by the failure of their master's theory to account for simple facts, e.g., that "bees, geese, flags, etc. are not always driven to the West" (as Varāhamihira put it). They changed and reinterpreted his words in accordance with the prevailing paradigm [Yano 1980].

In China, the notion of progress is present in the scepticism of the "Prince of Pharmacists," Li Shih-Chen, and in the criticisms by thirteenth century Chinese mathematicians of earlier empirical methods. Needham [1959: 104] quotes Yang Hui as writing:

> The men of old changed the name of their methods from problem to problem, so that as no specific explanation was given, there is no way of telling their theoretical origin or basis.

Needham is especially eloquent on progress in the many passages he devotes to Wang Chhung of the first century A.D., "one of the greatest men of his nation in any age" [1956: 368]. In his discourses on thunder and lightning

and on tidal movements [1959: 480–1; 485–8], Wang Chhung first refutes the beliefs of his predecessors with the help of arguments, examples and counter-examples, and then establishes his own theories in which he recognizes that lightning is essentially fire and that the tides depend on the moon.

I shall close with an example from India but cannot refrain from first quoting a contemporary scholar already mentioned who exhibits the kind of basic ignorance that Asian studies will never counter unless they occupy a more central place in our Western curriculum. A.C. Crombie writes at the beginning of his 1975 study on early Western attitudes to scientific progress:

> The idea is found only at the most critical level of literacy and can be found only in societies with historical records and a historical sense. (...) So far as I know, of the great ancient civilizations, only the Greeks and Hebrews in the West and the Chinese in the East developed this sense of history. The Egyptians, Babylonians and Hindus seem to have been primarily mythopoeic. [Crombie 1975: 213]

These words do not affect the grammarian Pāṇini who wrote his grammar of Sanskrit almost a millennium before anything to which the term "Hindu" could apply. Pāṇini lived on the upper Indus in what is now Pakistan and was then a distant corner of the Achaemenid Empire. His grammar was followed, after more than a century, by a series of "glosses" (*vārttikas*) attributed to Kātyāyana. These are known from their extensive discussion by Patañjali in his "Great Commentary," dated 150 B.C. To a modern Westerner, the term *commentary* evokes slavish dissection and lack of originality; what we want is scientific revolutions. In Asia, composing commentaries is a civilized form of making progress.

Early Western scholars argued that Kātyāyana was an opponent of Pāṇini who tried to find fault with him and that Patañjali attempted to justify Pāṇini by refuting Kātyāyana. Franz Kielhorn, a German Professor of Oriental Languages at Poona, refuted these theories in 1876 in a small booklet that has been accepted as definitive by most later scholars – a good specimen of objective

scholarship in the human sciences. Kielhorn first showed that Kātyāyana justified the rules of Pāṇini as often as he found fault with them. He then demonstrated the essential correctness of the definition of "gloss" given, two thousand years later, by the grammarian Nāgojībhaṭṭa:

> *sūtre 'nuktaduruktacintākaratvaṃ vārttikatvam"*,

paraphrased by Kielhorn as: glosses "consider whether anything has been omitted in the *sūtras* that should have been stated, and whether there is in them anything that is superfluous, faulty, or objectionable".

Coming to Patañjali, Kielhorn showed that he gave reasons for rejecting some of the glosses and for accepting others. He concluded that Patañjali, who started commenting on Kātyāyana, adopted his method and carried it further:

> Finding that Kātyāyana had left unnoticed certain *sūtras* of Pāṇini which were or which might appear to be liable to objection, he drew those rules within the range of his discussion, and either refuted the objections to which they seemed to be open, or showed that Pāṇini was really in the wrong and that his rules ought to be corrected. Or finding that Kātyāyana had failed to notice objections to rules which *had* been discussed by him, he thought it necessary to do what had been left undone by his master. On the other hand, not approving of the way in which certain objections had been met by Kātyāyana, or finding that the objections refuted by the latter admitted of different refutations, he either substituted his own refutations for those of Kātyāyana, or strengthened the views held by that scholar by additional arguments of his own. [Kielhorn 1876: 51–52]

Kielhorn continued in this vein and concluded:

> Nowhere does Patañjali explain Pāṇini for the simple purpose of explanation, but like a second Kātyāyana, he enquires whether anything has been omitted in the *sūtras* that should have been stated, or whether in them there is anything superfluous, faulty, or at all liable to objection [page 56].

My final remark on Pāṇini is taken from the Kyoto Sanskritist Yutaka Ojihara who died in 1991. Ojihara examined some phrases from Patañjali's "Great Commentary" that appear to treat Pāṇini as an infallible authority. One passage depicts him composing sūtras while seated on clean soil, facing East and with a ring of ritual grass around his fourth finger. "This being so", writes Patañjali, "it is impossible that even one sound should be without meaning".

Ojihara [1978: 219–234] demonstrated that such statements do not show that Pāṇini's rules were held to be beyond criticism, but that they had to be thoroughly examined in order to find out their ultimate motivation. Not all later grammarians retained this methodology but they continued to perfect the discipline and if it could not be done by stretching their predecessors' words, they founded their own school.

It will not surprise you that according to some Western Sanskrit scholars, Patañjali's compliment to Pāṇini indicates that Indian linguistics was shrouded in magico-religious beliefs and can have nothing to do with modern science. Pāṇini alas! did not leave a box with manuscripts behind. The scientifically relevant and decidable question, however, is not what he believed, but whether the then prevailing forms of the Sanskrit language can be correctly derived from the rules of his grammar.

My words do not deserve interpreters on the classical level of a Kātyāyana or Patañjali, or even modern masters like Kielhorn or Ojihara, but if they find critics as shrewd and fair, I shall be grateful and delighted.

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Colophon ☙

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